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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>6</sup> :</b> <b>A61K 35/00, 35/30, 35/48</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 96/28174</b> <b>(43) International Publication Date:</b> 19 September 1996 (19.09.96)
<b>(21) International Application Number:</b> PCT/US96/03337 <b>(22) International Filing Date:</b> 12 March 1996 (12.03.96) <b>(30) Priority Data:</b> 08/402,387 13 March 1995 (13.03.95) US <b>(71) Applicant (for all designated States except US):</b> UNIVERSITY OF SOUTH FLORIDA [US/US]; 4202 E. Fowler Avenue FAO 126, Tampa, FL 33620-7900 (US). <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only):</b> SANBERG, Paul, R. [US/US]; 11751 Pilot Country Drive, Spring Hill, FL 34610 (US). CAMERON, Don, F. [US/US]; 18206 Clear Lake Drive, Lutz, FL 33549 (US). BORLONGAN, Cesario, V. [PH/US]; 17802-A Jamestown, Lutz, FL 33549 (US). HELLER, Richard [US/US]; 1102 Pine Ridge Circle West, Brandon, FL 33511 (US). <b>(74) Agent:</b> KOHN, Kenneth, I.; Kohn & Associates, Suite 410, 30500 Northwestern Highway, Farmington Hills, MI 48334 (US).		<b>(81) Designated States:</b> AL, AM, AU, BB, BG, BR, CA, CN, CZ, EE, FI, GE, HU, IS, JP, KG, KP, KR, LK, LR, LT, LV, MD, MG, MK, MN, MX, NO, NZ, PL, RO, SG, SI, SK, TR, TT, UA, US, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i>
<b>(54) Title:</b> SERTOLI CELLS AS TRANSPLANTATION FACILITATOR FOR CELL TRANSPLANTATION  <b>(57) Abstract</b>  A method of producing a sustained localized immunosuppressive effect in localized tissues is achieved by transplanting Sertoli cells proximate to the tissue.		

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**SERTOLI CELLS AS TRANSPLANTATION FACILITATOR  
FOR CELL TRANSPLANTATION**

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**TECHNICAL FIELD**

5           The present invention relates to methods of transplanting cells to create a localized immunosuppressive and trophic effect in tissue.

**BACKGROUND OF THE INVENTION**

10           Transplantation of cells and tissues is being utilized therapeutically in a wide range of disorders including but not limited to from cystic fibrosis (lungs), kidney failure, degenerative  
15 heart diseases to neurodegenerative disorders.

          As an example, the central nervous system (CNS) (brain and spinal cord) has poor regenerative capacity which is exemplified in a number of neurodegenerative disorders. An example  
20 of such a disorder is Parkinson's disease. The preferred pharmacotherapy for Parkinson's disease is L-dopa which helps the symptoms of this disease in humans. However, the neuropathological damage and the debilitating progression is not reversed by  
25 this treatment protocol.

Laboratory and clinical studies have shown the transplantation of cells into the CNS is a potentially significant alternative therapeutic modality for neurodegenerative disorders such as

5 Parkinson's disease (Wictorin et al., 1990; Lindvall et al., 1990; Sanberg et al., 1994; Bjorklund and Stenevi, 1985; Freeman et al., 1994). In some cases, transplanted neural tissue can survive and form connections with the CNS of the

10 recipient (i.e. the host) (Wictorin et al., 1990).

When successfully accepted by the host, the transplanted tissue (i.e. the graft) has been shown to ameliorate the behavioral deficits associated with the disorder (Sanberg et al., 1994). The

15 obligatory step for the success of this kind of treatment is the prevention of graft rejection (i.e. graft acceptance).

Currently, fetal neural tissue is the primary graft source for neural transplantation

20 (Lindvall et al., 1990; Bjorklund, 1992; Isacson et al., 1986; Sanberg et al., 1994). Other viable graft sources include adrenal chromaffin cells and various cell types that secrete neural growth factors and trophic factors. The field of neural

25 tissue transplantation as a productive treatment protocol for neurodegenerative disorders has

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received much attention resulting in its  
progression to clinical trials. Preliminary  
results and clinical observations are promising  
although the graft rejection phenomenon remains a  
5 problem.

Recently, studies have suggested that  
Sertoli cells, when simultaneously transplanted  
with pancreatic islet cell into the diabetic rat,  
act as an effective local immunosuppressant on the  
10 host tissue (Selawry and Cameron, 1993). As a  
result, the graft is not rejected and the islets  
remain viable allowing the transplanted  $\beta$ -cells to  
function normally and produce insulin for an  
indefinite period of time. As a result, the  
15 accepted graft overcomes the primary physiological  
dysfunction of hyperglycemia thereby alleviating  
the related complications of this endocrine  
disorder. This cell transplantation protocol is  
accomplished without prolonged systemic  
20 immunosuppression, otherwise necessary when islets  
are transplanted without Sertoli cells.

In general, systemic immunosuppression is  
necessary if successful transplantation is to be  
achieved in humans. Immunosuppression of the  
25 entire body (i.e. systemic) can result, eventually,  
in graft acceptance. It is acquired, however, by

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placing the individual at medical risk making the immunosuppressant therapy itself more of a liability than a benefit in some cases. For a lack of a better immunosuppressant treatment, systemic immunosuppressants, with Cyclosporine-A (CsA) as the treatment choice, have been used as adjunctive therapy in neural and other transplantation protocols (Sanberg et al., 1994; Freeman et al., 1994; Borlongan et al., 1995). Arguably, systemic CsA treatment may be contraproductive to successful graft acceptance in the CNS because of its systemic effect and because CsA itself has been shown to cause detrimental side effects and may, in fact, be cytotoxic to neural tissues (Berden et al., 1985; de Groen et al., 1984).

It would be desirable to enhance the productive cell transplantation techniques already utilized for neurodegenerative disorders, such as Parkinson's disease, in ways which would more effectively slow the neurodegenerative disease process, more actively promote the re-establishment of normal neural tissue physiology and better alleviate the functional disabilities associated with the neural tissue dysfunction. Likewise, it would be desirable to avoid systemic immunosuppression with the ability to locally

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immunosuppress (i.e. at the graft site) by an immunosuppressant which is biologically tolerated by the host. Sertoli cells may provide this desired option since it is clear from the diabetic studies, as summarized above, that co-transplantation with Sertoli cells will deliver local immunosuppression and promote, therefore, efficient graft acceptance and functional restoration of the tissue-related dysfunction.

10

#### SUMMARY OF THE INVENTION AND ADVANTAGES

In accordance with the present invention, there is provided a method of producing a sustained localized immunosuppressive effect and trophic effect in tissue by transplanting Sertoli cells proximate to the tissue.

15

#### BRIEF DESCRIPTION OF THE DRAWINGS

Other advantages of the present invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

20  
25

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Figures 1A-B shows photomicrographs of two representative brain sections wherein the sections were stained with Lectin, the left side of each brain corresponds to the chromaffin cells transplanted side while the right side of each brain corresponds to the chromaffin cells with Sertoli cells the co-transplanted side;

Figures 2A-D show a higher magnification from the photomicrograph of Figure 1 of the transplant sites of brain sections illustrated in Figure 1; panels A and C show the chromaffin cells transplanted side while panels B and D show the side co-transplanted chromaffin cells with Sertoli cells;

Figure 3A-C are light micrographs illustrating cells from the ventral mesencephalon of fetal rats (VM) isolated and cultured for seven days in control medium (CM) or Sertoli cell pre-conditioned medium (SCM) and photographed with darkfield, interference contrast optics, wherein (A) depicts VM cells incubated in CM showing no evidence of stimulation or differentiation, (B) depicts VM cells incubated in SCM appearing highly stimulated, and (C) at higher magnification, depicts VM cells incubated in SCM exhibiting neurite outgrowth;



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Figure 4A-B are electron micrographs illustrating the cellular structure and tissue architecture of the Sertoli cell/chromaffin cell co-grafts in the striatum of the brain, wherein

- 5 (A) depicts electron dense chromaffin cells (arrows) easily identified because of the inclusion of secretory granules unique to these cells, and (B) shows the boxed area in (A) at higher magnification, with higher resolution, Sertoli  
10 cells (arrows) are seen immediately adjacent to the electron dense chromaffin cells;

- Figure 5A-B are electron micrographs illustrating (A) the striatum of the brain shows the penetration tract (arrows) and the site of  
15 Sertoli cell transplantation, and (B) shows the boxed area in (A) at higher magnification, with higher resolution, Sertoli cells (arrows) are easily identified because of the 1 $\mu$  latex bead inclusions which were loaded into the cells prior  
20 to transplantation; and

- Figure 6A-B are two light micrographs illustrating grafted Sertoli cells *in situ* labeled with a florescent tag (DiI) prior to their transplantation into the striatum of the brain  
25 wherein (A) depicts viable, florescent Sertoli cells in a rat host that had not received

immunosuppression therapy with Cyclosporine A (CsA), and (B) shows viable, florescent Sertoli cells in the rat host that had received cyclosporine A immunosuppression therapy.

5

#### DETAILED DESCRIPTION OF THE INVENTION

The present invention provides a method of producing a sustained localized immunosuppressive effect and trophic effect in  
10 tissue. This is achieved by the general step of transplanting Sertoli cells proximate to the tissue.

By sustained localized immunosuppressive effect, it is meant that the transplanted Sertoli  
15 cells will suppress the immunological response ordinarily mounted by the host tissue to the intrusion of foreign entities such as transplanted cells and that the immunosuppression will occur at the graft site (local) rather than by generalized  
20 immunosuppression of the entire body (systemic) which occurs with the ordinary methods of immunosuppression by agents such as CsA.

By tissue, it is meant any form of tissue including, but not limited to, cells, blood,  
25 organs, and disassociated cells.

In a preferred embodiment, the transplanted cells (which are intended to replace the dysfunctional cells or in some way alleviate tissue dysfunction) can avoid being rejected and thereby survive and functionally integrate into the host tissue. In the CNS, this will promote re-establishment of normal neural tissue function and thereby ameliorate the behavioral and functional deficits associated with the neurological and/or neurodegenerative disorder being treated. However, the method of the present invention can also be utilized with other transplantable cells or tissues other than neural tissue/cells such as endocrine cells, muscle cells, and other cells by utilizing similar techniques as those described for neural cells. Furthermore, the method of the present invention may be used for enhancing the outcomes of tissue and organ transplant, such as lung transplants, by providing localized immunosuppression. That is, Sertoli cells are used to facilitate transplant survival and graft function of the cells being transplanted.

With local immunosuppression by a Sertoli cell-derived immunosuppressant agent (which is now partially characterized), there would be no successful antibody or cellular immunological

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attack waged against the transplanted cells,  
including the Sertoli cells themselves.  
Additionally, since the immunosuppression is local  
and by a biologically tolerable agent, the side  
5 effects associated with both systemic  
immunosuppression and cytotoxicity of agents such  
as CsA would be avoided. Hence, the method of  
Sertoli cell transplantation provides a significant  
improvement over the use of systemic  
10 immunosuppression with CsA as the necessary  
adjunctive therapy to transplantation as shown in  
the example below.

The localized immunosuppression by a  
Sertoli cell-derived immunosuppressant agent can  
15 facilitate the survival of both xenografts and  
allografts. With allografts, co-transplantation  
with Sertoli cells should provide localized  
immunosuppression as to eliminate the need for  
systemic immunosuppression. With xenografts, co-  
20 transplantation with Sertoli cells may provide  
sufficient local immunosuppression so as to  
eliminate the need for systemic immunosuppression or  
the Sertoli cells may be used in combination with a  
systemic immunosuppressant to prevent rejection  
25 thereby reducing the dosage of systemic  
immunosuppressant required. When co-transplanted,

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the Sertoli cells not only provide immunosuppression, but provide regulatory, nutritional, and other factors designated as trophic support to the co-transplanted tissue.

- 5 Therefore, the Sertoli cells will not only provide inhibition of the immune response, but will allow enhanced growth and viability of allografts and xenografts by concomitant trophic support.

The source of Sertoli cells is by primary  
10 cell isolation from the mammalian testis. The protocol for harvesting the cells is well-defined (Cameron and Muffly, 1991; Griswold, 1992) and considered a routine methodology. In most of the published reports of Sertoli cell co-  
15 transplantation, cells are derived from the rat (Selawry and Cameron, 1993). Although rat Sertoli cells are utilized in the following examples, it is contemplated that the method of the present invention can be used with Sertoli cells from any  
20 suitable mammalian source. A preferred source of Sertoli cells for use with mammals, such as humans, are porcine Sertoli cells. However, if available and suitable, human Sertoli cells may be utilized.

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In one embodiment, the Sertoli cells are co-transplanted with the selected neural tissue or other appropriate tissue into the CNS by intracranial infusion (Sanberg et al., 1995).

5 By proximate to the tissue, it is meant that the Sertoli cells are placed in general proximity to the selected tissue such as the neural tissue. Generally, this means that the Sertoli cells can be infused or transplanted into any  
10 mammal so as to become located in proximity to the selected tissue. For example, the location can be any site where there is neural tissue such as the CNS, PNS, or fluids which bathe neural tissue such as cerebral spinal fluid and blood, blood vessels,  
15 or other tissues which are enervated such as endothelial tissue, muscle tissues, end organs, etc. The proximity of the Sertoli cells to the neural tissue is determined by the specific neural cells and function sought to be restored in a given  
20 transplantation. Additionally, in transplants involving non-neural tissue, the proximity of the Sertoli cells is determined by the specific tissue being transplanted.

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The source of neural cells for transplantation depends on the neurological disorder being treated. For example, Parkinson's disease is treated with ventral mesencephalic tissue (Lindvall et al., 1990) or chromaffin cells (Lindvall et al., 1987), Huntington's disease is treated with striatal lateral eminence cells (Isacson et al., 1986) and neurological pain is treated with adrenal chromaffin cells (Sagen et al., 1993). Other tissue types experimentally transplanted into specific animal models of human neurodegenerative disorders are summarized elsewhere (Dunnett and Bjorklund, 1994) and provide detailed descriptions of cell isolation and transplantation methods. Other non-neural tissues that have been transplanted are generally reviewed elsewhere (Sanberg, 1992) and provide detailed descriptions of cell isolation and transplantation methods.

The present invention also teaches a method of producing a sustained localized immunosuppressive effect in a target tissue by transplanting porcine Sertoli cells into the tissue. For example, transplanting porcine Sertoli cells into the central nervous system (CNS) of a subject, the cells secreting trophic factors in

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situ, for treating neurological disorders including epilepsy, stroke, Huntington's disease, head injury, spinal injury, pain, Parkinson's disease, myelin deficiencies, muscular dystrophy and other  
5 neuromuscular disorders, neurological pain, amyotrophic lateral sclerosis, Alzheimer's disease, and affective disorders of the brain.

The following examples demonstrate the methods of use of the present invention as well as  
10 efficacy for producing a sustained localized immunosuppressive effect.

#### EXAMPLE 1

##### Materials and Methods

15 Sprague-Dawley male rats, six weeks old, which were obtained from Harlan Sprague-Dawley, Inc. (Indianapolis, IN), were used. The animals were housed in individual Plexiglas cages in a room with controlled humidity and temperature and under  
20 a 12 hour light-dark cycle. Food and water were freely available ad lib.

##### Cell Culture

Bovine chromaffin cells were obtained from the laboratory of Dr. Jaqueline Sagen at the  
25 University of Chicago at Illinois. Upon arrival, cells were plated using DMEM-F12 media with serum.



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Cell counts using the tryphan blue method revealed a total of  $8 \times 10^{-6}$  per ml of surviving cells. A 95% viability of chromaffin cells were measured at the day of arrival and during the day of  
5 transplantation. Half of the chromaffin cells solution was co-cultured overnight with Sertoli cells.

The preparation of Sertoli cells is according to the method described by Selawry &  
10 Cameron (Selawry and Cameron, 1993), which is incorporated herein by reference. Specifically, the testes were removed, chopped into several pieces, and placed in a 50 ml conical tube containing 50 ml of Ham's F12/DMEM media. The  
15 pieces were washed once by centrifugation at 800 X g for two minutes. The supernatant was aspirated, and the tissue resuspended in 40 ml of media containing 40 mg trypsin and 0.8 mg DNase in a sterile 250 ml Erlenmeyer flask. The flask was  
20 placed in an 37°C oscillating incubator at 60-90 osc/minutes for 30 minutes. This step removed Leydig cells.

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The tubules were then transferred to a 50 ml conical tube, and centrifuged at 800 X g for two minutes. The supernatant fraction was aspirated, and the pellet resuspended in 40 ml of 1 M glycine, 2 mM EDTA containing 0.01% soybean trypsin inhibitor and 0.8 mg DNase, and incubated at room temperature for ten minutes. This step lysed any residual Leydig cells. The cells were washed by centrifugation for two minutes, and the step repeated twice, or until the media was no longer cloudy. The pellet was resuspended by gentle homogenization with a glass Pasteur pipet in 40 ml of media containing 20 mg collagenase in an Erlenmeyer flask, and incubated at 37°C for five minutes with 60-90 osc/minutes.

The cell suspension was centrifuged at 800 X g for two minutes, and the pellet was resuspended by gentle homogenization with a Pasteur pipet in 40 ml media containing 40 mg collagenase and 0.2 mg DNase, and incubated in an Erlenmeyer flask at 37°C for 30 minutes with 60-90 osc/minutes. The cells were then washed by centrifugation for two minutes, and the process repeated at least three times to eliminate peritubular cells. The cells were resuspended by gentle homogenization with a Pasteur pipet in 40 ml

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media containing 40 mg hyaluronidase and 0.2 mg of DNase, and incubated at 37°C for 30 minutes with 60-90 osc/min. The cells were pelleted by soft centrifugation for two minutes, and washed at least 5 five times to eliminate germ cells.

The resultant Sertoli cell-enriched fraction was resuspended into 0.25 ml of media with the chromaffin cells for at least 24 hours before transplantation. During the day of 10 transplantation, the solution containing the Sertoli cell-enriched fraction and the chromaffin cells were resuspended using a Pasteur pipet then suctioned by a Hamilton syringe with a spinal needle of gauge 20.

15

#### Surgery

The surgical procedures were carried out in sterile conditions, as is well known in the art (Pakzaban et al., 1993). All animals were 20 initially anesthetized with 0.60 ml/kg of sodium pentobarbital, then placed in Kopf stereotaxic instrument. Bilateral striatal transplants were performed with coordinates set at: anteroposterior = +1.2, medialateral = +/-2.8; dorsoventral - 6.0, 25 5.9 & 5.8 (based on the atlas of Paxinos and Watson, 1984). The right hemisphere of the brain

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was transplanted with bovine chromaffin cells while the left hemisphere received chromaffin cells plus Sertoli cells. Each side received a total volume of 3  $\mu$ l of the cell cocktail solution (1  $\mu$ l per DV site). After surgery, the animals were placed on heating pads until recovery. Animals received a short course of immunosuppression using Cyclosporine-A (20 mg/kg/d,i.p.) immediately after surgery and on the day following the transplant.

10 All animals were sacrificed at one month post transplant.

### Histology

Animals were anesthetized with 0.70 ml/kg of sodium pentobarbitol, then perfused with 500 ml of 0.9% isotonic saline and 500 ml paraformaldehyde. The animals were then decapitated, and the brain removed and post-fixed overnight in 40% paraformaldehyde with 30% sucrose in PBS. The following day, brain sections were cut at 30 microns using the Vibroslice (Campden Instrument, UK). Host tissue immunologic response was analyzed using the Lectin method (see below). Three experimenters conducted independent qualitative comparisons of the left and right side of the brain in a blind-randomized manner.

Lectin Method

Following vibrotome sectioning, brain sections were placed in 0.1% Triton X-100 for 15-30 minutes. The sections were then washed in 0.1M cationic PBS (pH 7.2), containing 0.1mM  $\text{CaCl}_2$ , 0.1mM  $\text{MgCl}_2$ . Incubation of sections was carried out in 20.0  $\mu\text{g/ml}$  lectin made in cationic PBS at 4°C for two hours. Rinsing, three times in PBS was done prior to incubation with DAB. The DAB stock solution was made by dissolving 10mg DAB in 20 ml phosphate buffer (0.1 M, pH 7.2) and adding 0.5 ml of 1%  $\text{CoCl}_2$  to DAB solution while stirring. Sections were first preincubated in DAB solution for 15 minutes. Upon adding 0.6 ml 3%  $\text{H}_2\text{O}_2$  to 20.5 ml DAB solution, incubation lasted for five to ten minutes or until appropriate reaction was reached. Sections were again rinsed three times in PBS. Finally, sections were mounted from distilled water to wash out salts.

20 RESULTS

Histological analyses of both transplant sites revealed that the transplanted side with chromaffin cells alone had greater glial infiltration and higher number of macrophages than the transplanted side with chromaffin cells plus Sertoli cells (Figures 1 & 2). No significant

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difference in glial response was observed between animals treated with or without cyclosporine.

Two conclusions are made from the data:

- 1) a localized effect of the Sertoli cells which  
5 appeared to suppress the immune response of the host tissue to the transplanted cells, and 2) a sustained immunosuppression, with or without a short course of CsA administration, can be achieved with simultaneous transplantation of chromaffin  
10 cells with Sertoli cells (Figure 4).

It can therefore be concluded that Sertoli cells can provide an immunologically privileged site in the CNS by direct intracranial infusion. Furthermore, with significant  
15 immunosuppression obtained following xenografts in the present study, Sertoli cells can provide greater beneficial effects on creating immunologically privileged sites following allografts, and enhance survival and integration of  
20 the transplant through immunological and trophic support.

**EXAMPLE 2**

Specific Protocol: The protocol involves three basic steps, Sertoli cell isolation, co-culture with neural specific cells or other appropriate  
5 cells and transplantation of the co-culture into the CNS (for details regarding the cell isolation see Selawry and Cameron (1993) and for details regarding cell transplantation see (Pakzaban et al., 1993).

10

**1A. Sertoli cell isolation**

The isolation procedure follows a well-defined method as described in reference (Selawry and Cameron, 1993). The cell culture medium used  
15 in all isolation steps and in which the cells were incubated was DMEM:Hams F12 supplemented with retinol, ITS and gentamicin sulfate (Cameron and Muffly, 1991). Testes were surgically collected from sixteen day old male Sprague-Dawley rats. The  
20 testes were decapsulated and prepared for enzymatic digestion to separate other testicular cell types from the Sertoli cells. The enzymatic procedure using collagenase (0.1%), hyaluronidase (0.1%) and trypsin (0.25%) is routinely used in many cell  
25 isolation protocols. After sequential enzymatic digestion, the Sertoli cell isolate was washed with

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culture medium, transferred to sterile cell culture vessels and placed in a humidified, 5% CO<sub>2</sub>-95% air tissue culture incubator. Following forty-eight hours of pre-incubation in a 39°C incubator, the

5 Sertoli cells were washed to remove any contaminating debris. The resultant Sertoli cell-enriched fraction was resuspended into 0.25 ml of DMEM/F12 medium, and incubated at 37°C for at least 24 hours.

10 The Sertoli cells were liberated from the vessel floor with 0.01% trypsin, transferred to a sterile conical test tube and repeatedly washed by centrifugation and then treated with trypsin inhibitor to cease the enzymatic action of trypsin.

15 During the day of transplantation, the Sertoli cell-enriched fractions are resuspended and suctioned by a Hamilton syringe with a twenty gauge spinal needle.

20 1B. Isolation and Pretreatment of Sertoli Cells

As previously described (Cameron and Muffly, 1991) decapsulated rat testes were subjected to sequential enzymatic treatment at 37°C using 0.25% trypsin (Sigma) and 0.1% collagenase

25 (Sigma, type V) (Cameron and Muffly, 1991). The resulting Sertoli cell aggregates were equally



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distributed in a volume of 20ml incubation medium into 75cm<sup>2</sup> tissue culture flasks (Costar). Plated Sertoli aggregates were incubated at 39°C in 5% CO<sub>2</sub>-95% air for 48 hours after which cells were

5 subjected to hypotonic treatment with sterile 0.5mM Tris-HCl buffer for one minute (Galdieri et al. 1981) to expedite the removal of contaminating germ cells. Following two washes with incubation medium, flasks were replenished with 20ml

10 incubation medium and returned to the CO<sub>2</sub>-injected incubator at 37°C in 5% CO<sub>2</sub>-95% air. The resulting pre-treated Sertoli-enriched monocultures contained greater than 95% Sertoli cells. Plating density ( $< 2.0 \times 10^6$  Sertoli cells/cm<sup>2</sup>) did not result in a

15 confluent monolayer of cells.

## 2. Co-culture with neural specific cells

Sertoli cells and neural cell specific for transplantation for the neurodegenerative model

20 were suspended by trypsin (0.01%), washed three times with medium and placed into a sterile cell culture vessel twenty-four hours prior to transplantation. The resulting co-culture was placed in a 5% CO<sub>2</sub>-95% air incubator at 37°C until

25 utilized for transplantation.

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### 3. Transplantation of co-culture into the CNS

The transplantation protocol follows the procedure as previously described by Pakzaban et al., (1993). The animal surgery was carried out in  
5 sterile conditions. All animals were initially anesthetized with 0.60 ml/kg sodium pentobarbital, then placed in a Kopf stereotaxic instrument. For the Parkinson's disease model, unilateral striatal transplants are performed with coordinates set at:  
10 anteroposterior - +1.2, mediolateral - +/-2.9, dorsoventral - 6.0, 5.9 and 5.8 (based on the atlas of Paxinos and Watson) (1984). Different coordinates are used for different neurodegenerative animal models also based on  
15 Paxinos and Watson (1984). The striatum ipsilateral to the lesioned substantia nigra is transplanted with Sertoli cells or with the Sertoli cell co-culture. Each striatum receives a total volume of 3µl of Sertoli cell or co-culture  
20 suspension. One microliter of the cell suspension was infused over one minute per dorsoventral site. Another five minutes was then allowed upon reaching the last dorsoventral site before retracting the needle. After surgery, the animals were placed on  
25 heating pads until they recovered. The animals received a short course of immunosuppression

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therapy using Cyclosporine-A (20 mg/kg/d, i.p.) immediately after surgery and on the day following the transplant.

Sertoli cells and/or co-culture

5 suspensions are transplanted into animal models of various neurodegenerative disorders by stereotaxic coordinates defined for the specific disorder, as illustrated in the Parkinson's disease example. All experimental animals are systematically assayed  
10 for functional recovery by techniques specific to that animal model.

### EXAMPLE 3

Figure 4A illustrates that electron dense  
15 chromaffin cells (arrows) were easily identified because of the inclusion of secretory granules unique to the cells. Figure 4B shows the boxed area in Figure 4A at a higher magnification, wherein at a higher resolution, Sertoli cells  
20 (arrows) were detected immediately adjacent to the electron dense chromaffin cells. This demonstrates the survival of co-grafted adrenal chromaffin cells with Sertoli cells in the brain.

(1) Growth of neural cells**Incubation Medium and Sertoli Cell Pre-Conditioned Medium:**

The incubation medium used for Sertoli  
5 cell culture and co-culture was Dulbecco's Minimum  
Essential Medium:Hams F12 Nutrient Medium  
(Whittaker Bioproducts) mixed 1:1 and supplemented  
with 3mg/ml L-glutamine (Sigma, grade III),  
0.01cc/ml insulin-transferrin-selenium (ITS,  
10 Collaborative Research, Inc.), 50 ng/ml retinol  
(Sigma), 19µl/ml lactic acid (Sigma) and 0.01cc/ml  
gentamicin sulfate (Gibco).

Following the first 48 hour incubation  
period of isolated Sertoli cells, media was  
15 collected and centrifuged at 1500rpm for five  
minutes. The supernatant was collected and  
immediately frozen in sterile test tubes. This  
medium was identified as Sertoli pre-conditioned  
medium (SCM).

**20 Isolation and Incubation of Fetal Brain  
Cells:**

Fetal brain cells (FBC) were collected  
from the ventral mesencephalon of fetal rats (15-17  
days gestation). The fetal brain tissue was  
25 suspended in medium and initially dispersed by  
passing it through a series of sequentially

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decreasing sized hypodermic needles (18-26 gauge).  
The resulting suspension was treated with 0.1%  
trypsin for five minutes and followed by 0.1%  
trypsin inhibitor for two minutes. The suspended  
5 FBC were washed (three times), resuspended in  
incubation medium and plated in poly-L-lysine-  
coated culture vessels.

Cells from the ventral mesencephalon of  
fetal rats (VM) were isolated and cultured for  
10 seven days in control medium (CM) or Sertoli cell  
pre-conditioned medium (SCM) as shown in Figure 3A,  
VM cells incubated in CM showed no evidence of  
cellular stimulation or differentiation. Referring  
to Figure 3B, VM cells incubated in SCM were highly  
15 stimulated. Figure 3C illustrates that at higher  
magnification, VM cells incubated in SCM show  
neurite outgrowth.

#### **EXAMPLE 4**

20 **Incorporation of latex beads:** Sertoli  
cells were isolated and prepared for incubation as  
described. Prior to transplantation (approximately  
12 hours), sterile 1 $\mu$ m latex beads (10 $\mu$ l/ml medium;  
Pelco, Tustin, CA) were added to the incubation  
25 medium. Sertoli cells rapidly phagocytosed the  
beads. Immediately prior to transplantation, the

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beaded Sertoli cells were washed (three times) and resuspended in 1ml of incubation medium.

Referring to Figure 5A, Sertoli cells were transplanted into the striatum of the brain wherein the penetration tract (arrows) and the site of Sertoli cell transplantation are shown. At higher magnification as shown in Figure 5B, Sertoli cells (arrows) were easily identified because of the inclusion of 1 $\mu$  latex beads which were loaded into the Sertoli cells prior to transplantation.

#### EXAMPLE 5

##### Effects of Cyclosporine A (CsA) on the survival of transplanted Sertoli cells

**Fluorescent cell labeling:** Immediately prior to transplantation (approximately two hours), Sertoli cell monocultures were treated with CM-DiI fluorescent dye for cell tracking (100 $\mu$ l stock/ml medium; Molecular Probes, Inc., Eugene, OR) for 7 minutes at 37°C and then placed in the refrigerator (4°C) for an additional 15 minutes. Fluorescent "tagged" Sertoli cells were washed (three times) and resuspended in 1ml of incubation medium.

The effect of cyclosporine A on the survival of grafted Sertoli cells *in situ* was examined. Grafted Sertoli cells were labeled with

-29-

a fluorescent tag (DiI) prior to transplantation into the striatum of the brain. The tissue was collected one month post-transplantation.

Referring to Figure 6A, viable fluorescent Sertoli  
5 cells were seen in a rat host that had not received immunosuppression therapy with cyclosporine A.

Referring to Figure 6B, viable fluorescent Sertoli cells are shown in a rat host that had not received cyclosporine A immunosuppression therapy. This  
10 example demonstrates that cyclosporine A is not necessary for the survival of Sertoli cells transplanted into the brain.

Throughout this application various publications are referenced by citation. Full  
15 citations for the publication are listed below. The disclosure of these publications in their entireties are hereby incorporated by reference into this application in order to more fully describe the state of the art to which this  
20 invention pertains.

The invention has been described in an illustrative manner, and it is to be understood the terminology used is intended to be in the nature of description rather than of limitation.

25 Obviously, many modifications and variations of the present invention are possible in light of the above teachings. Therefore, it is to

be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.



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-33-

**CLAIMS**

What is claimed is:

1. A method of producing a sustained localized immunosuppressive effect and trophic effect in target tissue by transplanting Sertoli cells proximate to the target tissue.

2. A method as set forth in claim 1 wherein said transplanting step is further defined as co-transplanting the Sertoli cells and transplant tissue of the same type as the target tissue into the target tissue.

3. A method as set forth in claim 2 wherein the Sertoli cells are co-transplanted with neural cells into a mammal's central nervous system.

4. A method as set forth in claim 3 wherein the neural cells co-transplanted with the Sertoli cells are first co-cultured with the Sertoli cells and the co-cultured cells are co-transplanted together.

5. A method as set forth in claim 1 wherein transplantation is further defined as direct infusing the Sertoli cells into the central nervous system.

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6. A method as set forth in claim 1 wherein the Sertoli cells are porcine Sertoli cells.

7. A method as set forth in claim 12, wherein the mammal suffers from neurological disorder or neural degeneration disorder including epilepsy, stroke, Huntington's disease, head injury, spinal injury, pain, Parkinson's disease, myelin deficiencies, neuromuscular disorders, neurological pain, amyotrophic lateral sclerosis, Alzheimer's disease, and affective disorders of the brain.

8. A method of producing a sustained localized immunosuppressive effect and trophic effect in a target tissue by transplanting porcine Sertoli cells into the central nervous system of a subject, the cells also secreting trophic factors *in situ*, for treating neurological disorders including epilepsy, stroke, Huntington's disease, head injury, spinal injury, pain, Parkinson's disease, myelin deficiencies, muscular dystrophy, neurological pain, amyotrophic lateral sclerosis, Alzheimer's disease, and affective disorders of the brain.

9. A method as set forth in claim 8, wherein the subject is human.

10. Use of Sertoli cells to produce a sustained localized immunosuppressive effect and trophic effect in target tissue by transplanting Sertoli cells proximate to the target tissue.

11. A use as set forth in claim 10 wherein said transplanting is further defined as co-transplanting the Sertoli cells and transplant tissue of the same type as the target tissue into the target tissue.

12. A use as set forth in claim 11 wherein the Sertoli cells are co-transplanted with neural cells into a mammal's central nervous system.

13. A use as set forth in claim 12 wherein the neural cells co-transplanted with the Sertoli cells are first co-cultured with the Sertoli cells and the co-cultured cells are co-transplanted together.

14. A use as set forth in claim 10 wherein transplantation is further defined as direct infusing the Sertoli cells into the central nervous system.

15. A use as set forth in claim 10 wherein the Sertoli cells are porcine Sertoli cells.

16. A use as set forth in claim 11, wherein the mammal suffers from neurological disorder or neural degeneration disorder including epilepsy, stroke, Huntington's disease, head injury, spinal injury, pain, Parkinson's disease, myelin deficiencies, neuromuscular disorders, neurological pain, amyotrophic lateral sclerosis, Alzheimer's disease, and affective disorders of the brain.

17. A use of Sertoli cells to produce a sustained localized immunosuppressive effect and trophic effect in a target tissue by transplanting porcine Sertoli cells into the central nervous system of a subject, the cells also secreting trophic factors *in situ*, for treating neurological disorders including epilepsy, stroke, Huntington's disease, head injury, spinal injury, pain, Parkinson's disease, myelin deficiencies, muscular dystrophy, neurological pain, amyotrophic lateral sclerosis, Alzheimer's disease, and affective disorders of the brain.

18. A use as set forth in claim 17, wherein the subject is human.

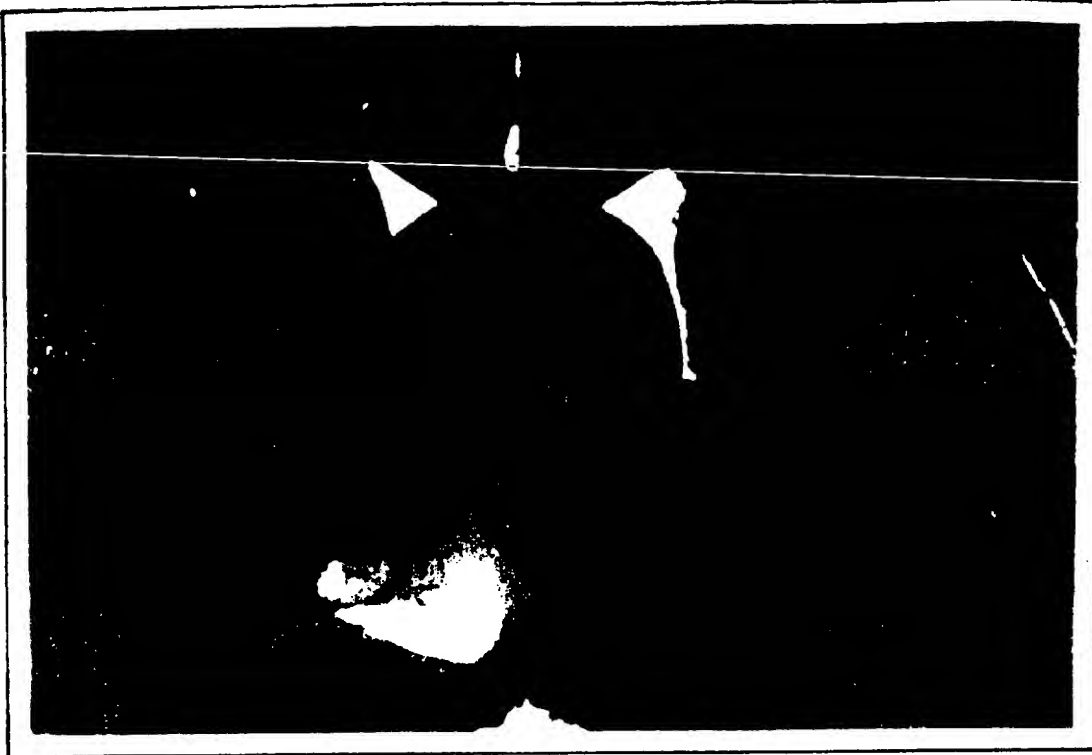


Fig - 1A



Fig - 1B



Fig - 2A

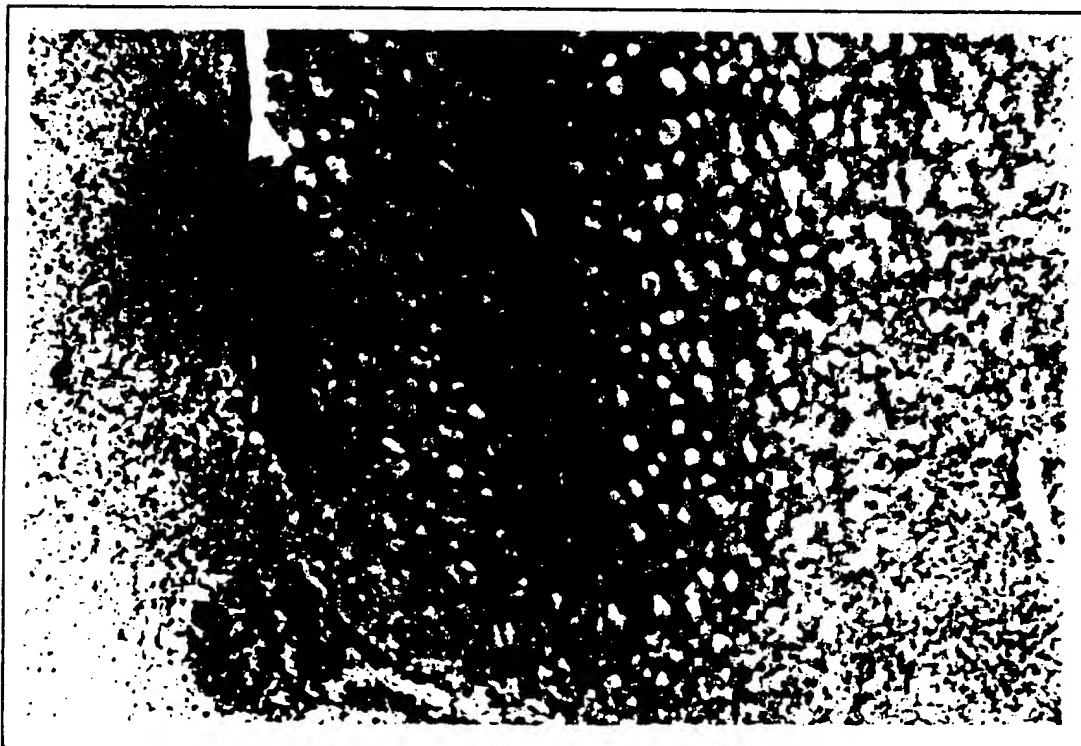


Fig - 2B





Fig - 2C

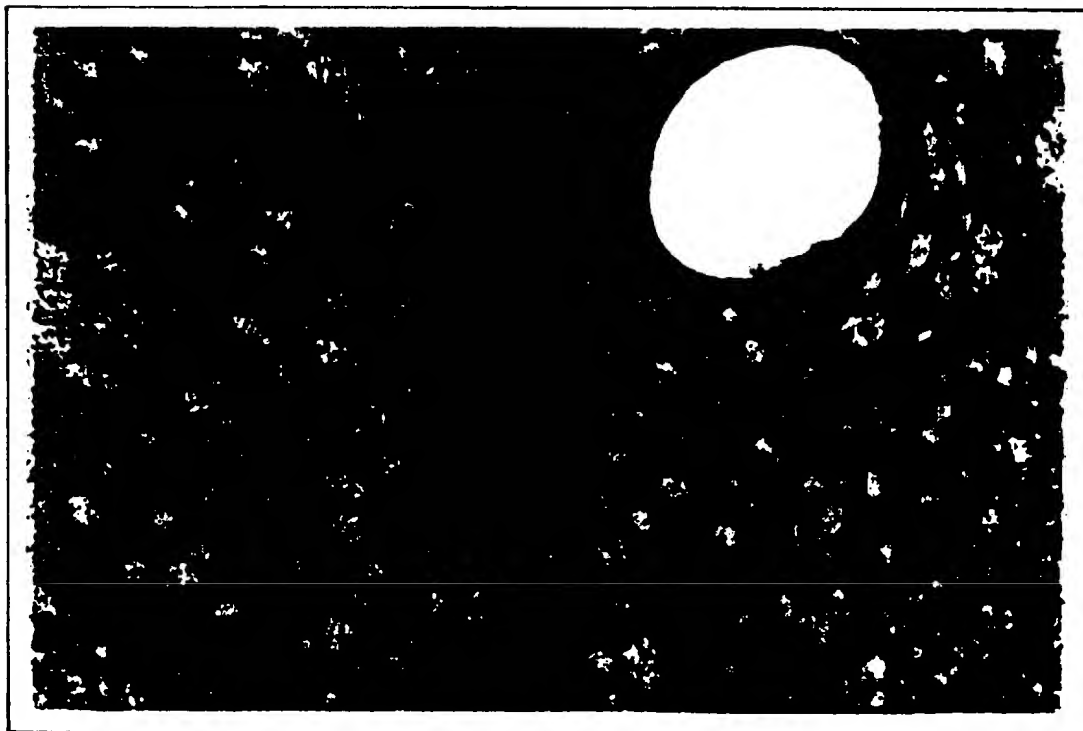


Fig - 2D

Fig - 3A

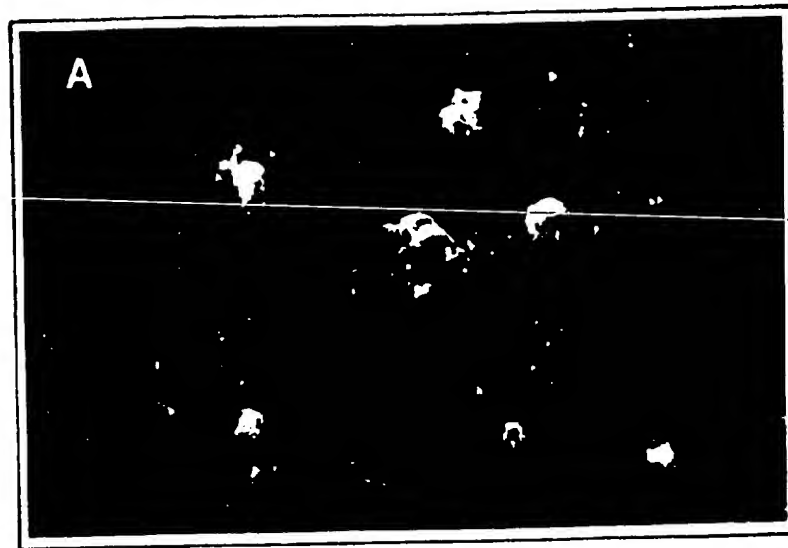


Fig - 3B

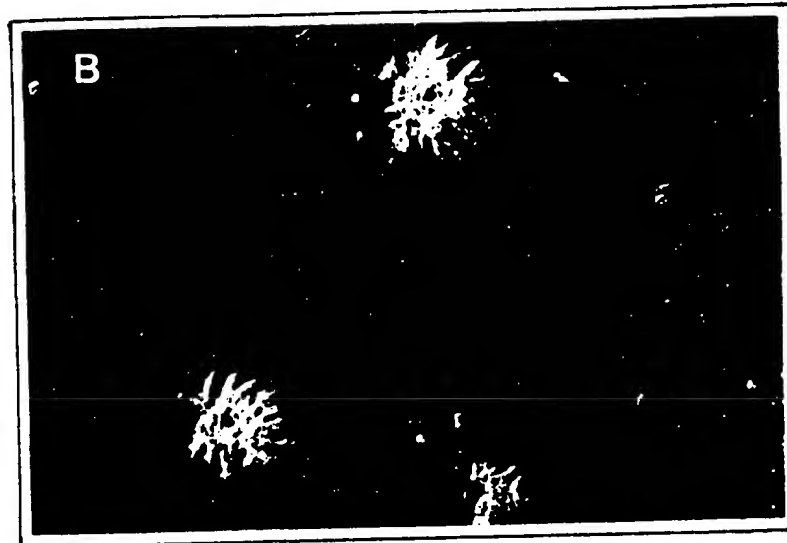
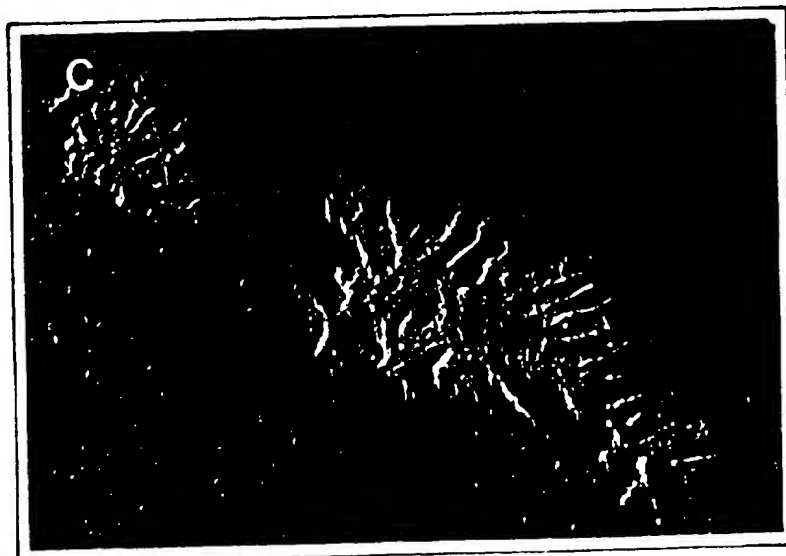


Fig - 3C



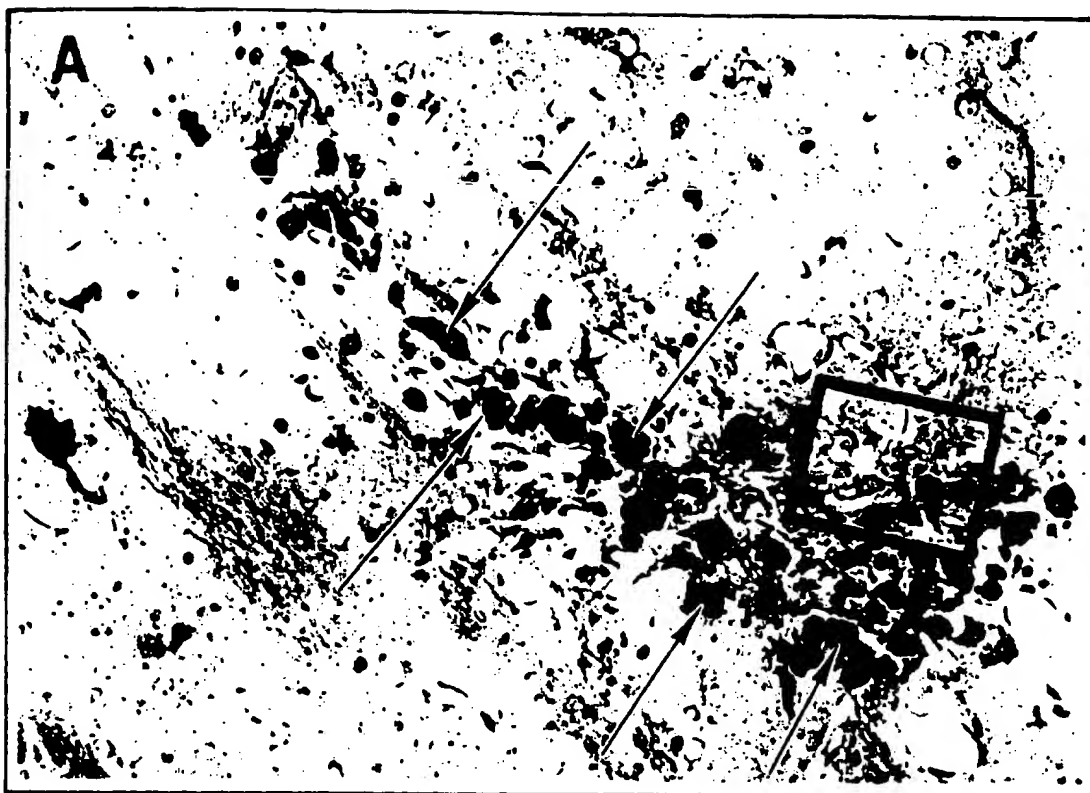


Fig - 4A



Fig - 4B

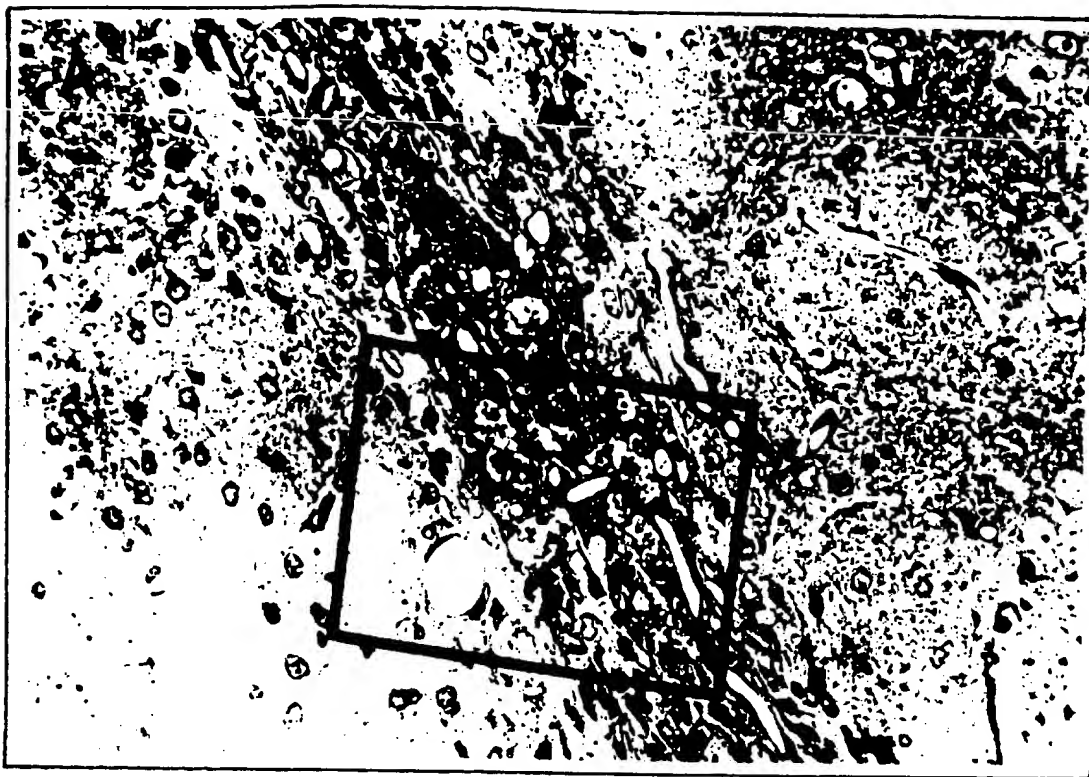


Fig - 5A



Fig - 5B

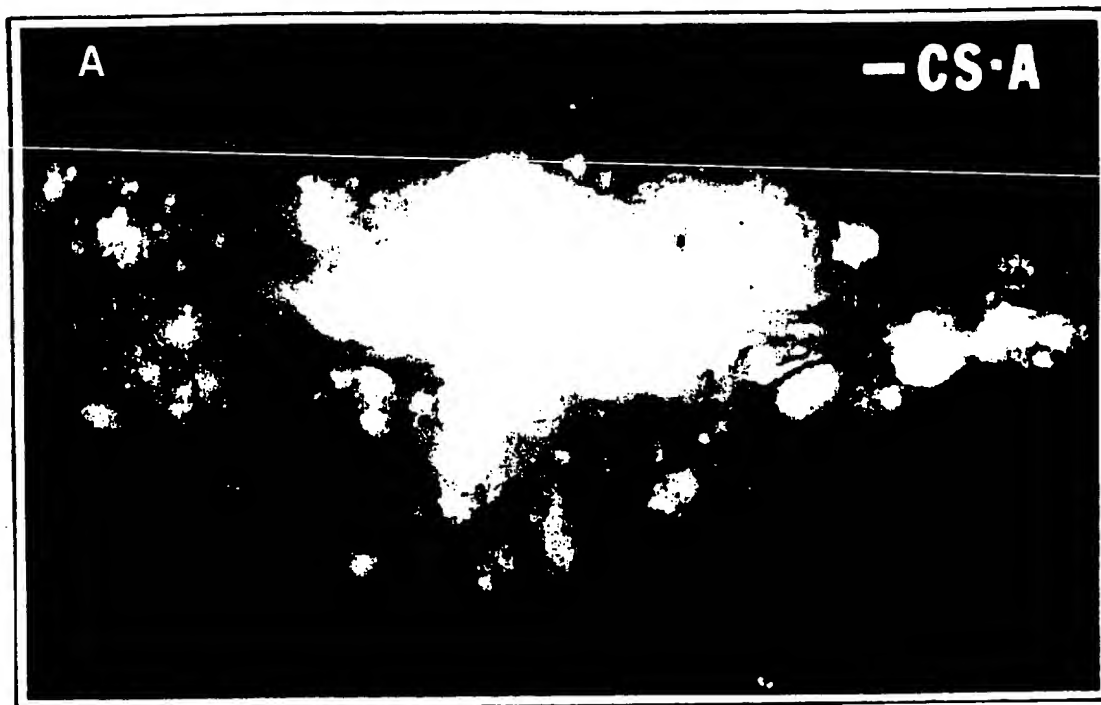


Fig - 6A

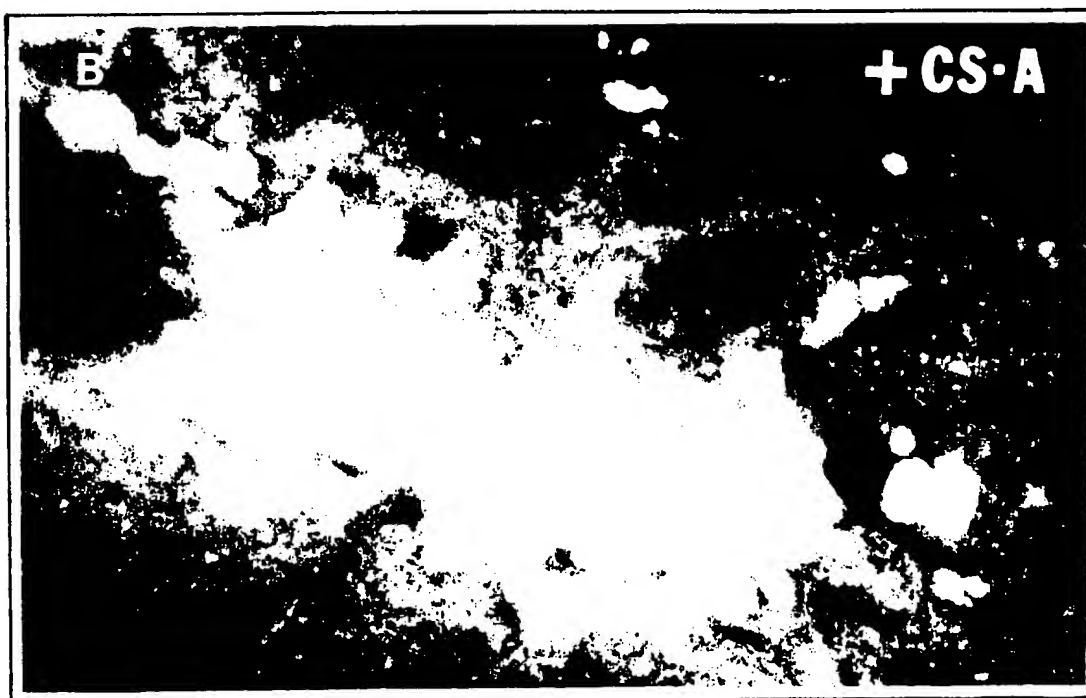


Fig - 6B

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US96/03337

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) : A61K 35/00, 35/30, 35/48

US CL : 424/93.1, 93.7, 559

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 424/93.1, 93.7, 559

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ----- Y	Cell Transplantation, Volume 2, issued 1993, Selawry et al, "Sertoli Cell-Enriched Fractions In Successful Islet Cell Transplantation", pages 123-129, see entire document.	1 ----- 2-18
Y	The Journal of Neuroscience, Volume 13, Number 6, issued June 1993, Sagen et al, "Transplants of Immunologically Isolated Xenogeneic Chromaffin Cells Provide a Long-Term Source of Pain-reducing Neuroactive Substances", pages 2415-2423, see entire document.	2-18

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means		
"P" document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 11 MAY 1996	Date of mailing of the international search report 13 JUN 1996
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer <i>Patricia A. Duffy</i> PATRICIA A. DUFFY Telephone No. (703) 308-0196

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US96/03337

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y, P	Society For Neuroscience Abstracts, Volume 21, Part 1, issued November 1995, Sanberg et al, "Functional Recovery In Hemiparkinsonian Rats Following Neural Transplantation of Testis-Derived Sertoli Cells", page 317, see abstract 133.12.	2-18
Y	EOS-Rivista Di Immunologia ed Immunofarmacologia, Volume 12, Number 2, issued 1992, DeCesaris et al, "Inhibition of Lymphocyte Activation By Sertoli Cell Immunosuppressive Factor(s)", page 86, see entire abstract.	2-18
Y, P	Nature, Volume 377, issued 19 October 1995, Bellgrau et al, "A role for CD95 Ligand in preventing graft rejection", pages 630-632.	2-18
A	Critical Reviews in Neurobiology, Volume 8, Number 3, issued 1994, Koutouzis et al, "Cell Transplantation for Central Nervous System Disorders", pages 125-161, see entire document.	1-18

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US96/03337

## B. FIELDS SEARCHED

Electronic data bases consulted (Name of data base and where practicable terms used):

MEDLINE, CAB ABSTRACTS, APS, EMBASE, DERWENT WPI, DERWENT BIOTECHNOLOGY ABSTRACTS,  
CONFERENCE PAPERS INDEX, JAPIO, BIOSYS

search terms: transplantation, sertoli cells, immunosuppression, trophic, factors, porcine, co-transplantation